

Claims

1. A power system for transferring power between a plurality of power sources comprising:

a first power source having a first pair of terminals associated therewith;

5 a second power source having a second pair of terminals associated therewith;

a third power source having a third pair of terminals associated therewith; and

a power converter including,

10 (i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of  
15 switches has an anti-parallel diode associated therewith;

(ii) a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the  
20 lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;

(iii) a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein  
25 said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;

(iv) a first inductor connected between the first common node and the second common node;

30 (v) a second inductor connected between the first common node and the third common node; and

(vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

operation for transferring power between at least a pair of said first, second, and third power  
35 sources.

2. A power system according to claim 1 wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner, the second power source is a battery, and the third power source is an ultracapacitor; and wherein said plurality of modes of operation include:

- 5 a battery-to-DC Link boost mode;  
a battery-to-ultracapacitor boost mode;  
an ultracapacitor-to-DC Link boost mode;  
a DC Link-to-battery buck mode;  
a DC Link-to-Ultracapacitor buck mode; and  
10 a battery-to-ultracapacitor buck mode.

3. A power system according to claim 2 further comprising an application electrically connected to the output of the power conditioner.

4. A power system according to claim 3 wherein said application further includes an inverter and a load connected to said inverter.

5. A power system according to claim 1 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

6. A power system according to claim 1 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

7. A power system according to claim 1 wherein the power converter control unit is configured to control ON/OFF conduction states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch  
5 arrangements during corresponding time intervals for each one of the plurality of modes of operation.

8. A power system for transferring power between a plurality of power sources comprising:

a first power source having a first pair of terminals associated therewith;

5 a second power source having a second pair of terminals associated therewith;

a third power source having a third pair of terminals associated therewith; and

a power converter including,

10 (i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of  
15 switches has an anti-parallel diode associated therewith;

(ii) a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the  
20 lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;

(iii) a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein  
25 said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;

(iv) a first inductor connected between the first common node and the second common node;

30 (v) a second inductor connected between the first common node and the third common node; and

(vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

operation for transferring power between at least a pair of said first, second, and third power  
35 sources; wherein said plurality of modes of operation include:

- a battery-to-DC Link boost mode;
- a battery-to-ultracapacitor boost mode;
- an ultracapacitor-to-DC Link boost mode;
- a DC Link-to-battery buck mode;
- 40 a DC Link-to-Ultracapacitor buck mode; and
- a battery-to-ultracapacitor buck mode.

9. A power system according to claim 8 wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner, the second power source is a battery, and the third power source is an ultracapacitor

10. A power system according to claim 9 further comprising an application electrically connected to the output of the power conditioner.

11. A power system according to claim 10 wherein said application further includes an inverter and a load connected to said inverter.

12. A power system according to claim 8 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

13. A power system according to claim 8 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

14. A power system according to claim 8 wherein the power converter control unit is configured to control ON/OFF conduction states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch  
5 arrangements during corresponding time intervals for each one of the plurality of modes of operation.

15. A power system for transferring power between a plurality of power sources comprising:

a first power source having a first pair of terminals associated therewith, wherein the first power source is a DC Link which derives from a fuel cell whose output is electrically connected to the input of a power conditioner;

a second power source having a second pair of terminals associated therewith, wherein the second power source is a battery;

a third power source having a third pair of terminals associated therewith, wherein the third power source is an ultracapacitor; and

a power converter including,

(i) a first pair of switches connected to the first pair of terminals, said first switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a first common node, and wherein each of the first pair of switches has an anti-parallel diode associated therewith;

(ii) a second pair of switches connected to the second pair of terminals, said second switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a second common node, and wherein each of the second pair of switches has an anti-parallel diode associated therewith;

(iii) a third pair of switches connected to the third pair of terminals, said third switch pair comprising an upper switch having a drain, a gate, and a source terminal, and a lower switch having a drain, a gate, and a source terminal, wherein said source terminal of said upper switch is electrically connected to the drain terminal of the lower switch thereby forming a third common node, and wherein each of the third pair of switches has an anti-parallel diode associated therewith;

(iv) a first inductor connected between the first common node and the second common node;

(v) a second inductor connected between the first common node and the third common node; and

(vi) a control unit configured to actuate the switches in the first, second, and third pairs of switches in accordance with one of a plurality of modes of

35 operation for transferring power between at least a pair of said first, second, and third power sources.

16. A power system according to claim 15 wherein the plurality of modes of operation include:

- 5 a battery-to-DC Link boost mode;  
a battery-to-ultracapacitor boost mode;  
an ultracapacitor-to-DC Link boost mode;  
a DC Link-to-battery buck mode;  
a DC Link-to-Ultracapacitor buck mode; and  
a battery-to-ultracapacitor buck mode.

17. A power system according to claim 15 further comprising an application electrically connected to the output of the power conditioner.

18. A power system according to claim 17 wherein said application further includes an inverter and a load connected to said inverter.

19. A power system according to claim 15 wherein the power converter switches of the first, second, and third pairs of switches are of the MOSFET type.

20. A power system according to claim 15 wherein the power converter switches of the first, second, and third pairs of switches are of the IGBT type.

21. A power system according to claim 15 wherein the power converter control unit is configured to control ON/OFF states of the switches to define a respective switch arrangement corresponding to each one of the plurality of modes of operation, the control unit being further configured to establish a sequence of switch arrangements during  
5 corresponding time intervals for each one of the plurality of modes of operation.